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Growth and Water Content Responses of the Selected Cassava (*Manihot esculenta* Crantz) Genotypes to Drought and Salinity; and their Effects on Yield

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Authors' contributions

All aspects of the research work was carried out by author BAM including the first draft under the professional supervision of Prof. Authors OJO and OSO helped with data collection. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To screen ten selected cassava genotypes for tolerance to drought and salinity using growth and yield attributes; and leaf relative water contents (LRWC) as screening tools.
Study design: The design was factorial consisting of ten cassava genotypes, three treatments (and control) with six replications laid out in a randomized complete block design(RCBD).
Place and Duration of Study: Department of Botany, University of Ibadan, between January and July, 2019.
Methodology: There were a total of 240 experimental units, 60 units in each group. It was a semi-field experiment. All plants were watered for 6 weeks before exposing them to the physiological stresses of drought (D), salinity (S) and their interaction (D×S). The designated plants were subjected to S by applying 100mM of NaCl solution, D by with-holding water for 2 weeks interval, (D×S) by combining the two stresses and the first block (the first 60 units) served as control.
Results: With respect to plant height, the least and most significantly affected by drought were IBA120008 (61.94 cm) and I098510 (32.77 cm); by salinity were IBA120008 (57.09 cm) and

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I920326 (35.24 cm) and by D×S were IBA120008 (67.45 cm) and I920326 (34.57cm), respectively. With respect to RWC at the final stage of growth, the most tolerant were TMEB419 (100.00%) under D, I980581 (100.00%) under S and I010040 (100.00%) under D×S while the most susceptible were TMEB693 (89.75%), IBA120008 (63.64%) and I070593 (55.56%) under D, S and D×S respectively. In all the three stresses, genotype I980581 was the least significantly affected with the tuber yield of 174.54g.

Conclusion: High shoot growth does not guarantee high yield. It can also be concluded that drought had more detrimental effects on cassava productivity than salinity and their combination.

Keywords: Cassava genotypes; Tolerance; Growth; Relative water content; drought and salinity.

1. INTRODUCTION

Plants are usually exposed to several environmental stresses that limit their growth, development and yield [1,2]. Among these abiotic stresses, water and salinity stresses pose greater threat to food security in arid and semiarid regions and coastal areas respectively. Dissolved solutes from irrigation can also accumulate over time in the soil to cause salt stress [1].

Cassava (*Manihot esculenta*) has more than 7,000 varieties [3]. Once a fibrous root becomes storage root, its ability to absorb water and nutrient reduce considerably [4]. It supplies energy for over 500 million people in tropical Africa [5]. Cassava serves as a food security crop and source of income for rural farmers in Nigeria [6].

Cassava is a rustic crop, well adapted to poor soils, but osmotic stresses such as drought or salinity are limiting factors for its cultivation. The increasing need for cassava as a food requires new cultivation soils but some of these are saline. Therefore, it is a major goal to have cassava plants more tolerant to salt [7].

Generally, the importance of water in agriculture cannot be over-emphasized [8]. Water stress is a reality in most rain-fed agricultural systems [9]. Due to scarcity and increasing contest for water between farmers and other sectors of production, the use of quality water is being compromised [10]. Drought prevents cassava and other plants from reaching their full genetic potentials [11].

Cassava (*Manihot esculenta* Crantz) is a perennial shrub of the new world [12]. It is mainly cultivated for its enlarged starchy roots, grows up to 1- 4m tall [13,14]; and is usually harvested 9-12 months after planting. It has a high degree of inter-specific hybridization and as such, the morphological features highly vary among the various cultivars [14]. It can be propagated either from stem cuttings or sexual seeds [15] but vegetative propagation by stem cuttings is mostly preferred [16].

The three major parts of a cassava plant are roots, stems and leaves (Plate 1); with the presence of flowers and fruits occasionally (seed propagation). The mature storage root can be differentiated into three distinct tissues; bark (periderm), peel (or cortex) and parenchyma [14]. Tuber formation largely depends on factors like temperature, photoperiod, plant genotype and assimilation [17]. Average tuber weight is between 4-7kg but tubers up to 40kg have been recorded [18].

Cassava is mainly cultivated in the low land tropics where there is warm climate [19]. It is sensitive to soils with pH greater than 7.8 and high sodium content [20].

Photosynthetic rate of higher plants is directly proportional to the LRWC and leaf water potential [21]. LRWC is a good indicator of water status than water potential in plants [11,22]. It reflects the balance between water supply to the leaf tissue and transpiration rate [23]. Therefore, estimating leaf water content is important in determining the health and productivity of vegetation [24].

Drought and salinity both have detrimental effects on the tissue water contents of plants [25,26]. Leaf tissue water deficit can be triggered not only by low soil water content but also by high vapour pressure deficit of the atmosphere [27].

Cassava can produce high yields under drought than other root crops [28]. Fresh cassava root tubers (Plate 2) are highly perishable due to short postharvest life than any of the major root crops [3,14]. The vulnerable stage of cassava to drought is from 1-5 months after planting (MAP); stages of root initiation and tuber formation [14]. Soil salinity has negative effects on crop yield [26,29]. Salinity affects both vegetative and reproductive developments in various plants [30].

The aim of the study was to screen the ten selected cassava genotypes for tolerance to drought and salinity using growth and yield attributes; and relative water contents as screening tools.

The basis of this research was to provide information on these new genotypes so as to help farmers and others concerned to select genotypes that is naturally best adapted to their soil types and environment (desert and/or coastal areas); hence, maximize yield.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out on the Research Farm of the Department of Botany, University of Ibadan, Ibadan, Oyo state.

2.2 Soil Sampling and Analysis

Soil samples were collected from the Nursery of Department of Botany, identified from Agronomy Department; University of Ibadan, and routine analysis was carried out (Table 1). Two hundred and forty bags (20 kg each) were filled with 15kg of soil. The bags were perforated for aeration and to release excess water if there is any. This made it a semi-field experiment because the plants were potted, treatments controlled while still exposed to natural environmental factors such as rain, direct sunlight, air etc.

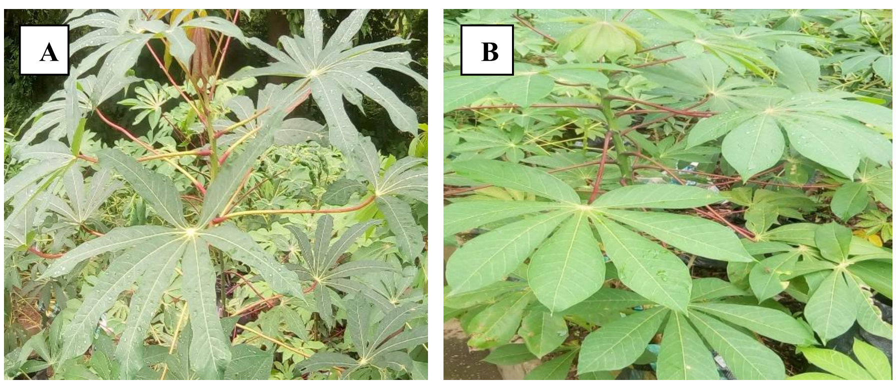

Plate 1. Pictures showing the leaf morphology of some of the selected cassava genotypes (2A and 2B)
A- IBA120008 and B- I980581.

Plate 2. Pictures showing the tuber yields of some of the cassava genotypes under salinity and the combined stress (3a and 3b)
a- I980581 (D×S) and b- I920326 (S).

2.3 Sources of Planting Materials

The stakes of the ten cassava genotypes were collected from the International Institute of Tropical Agriculture (IITA), Ibadan and were screened for tolerance to drought and salinity using growth and yield attributes; and leaf relative water content (LRWC), as the screening parameters. The ten cassava genotypes used in the present study were:

1.	IBA120008	2.	I098510
3.	I010040	4.	I070539
5.	TMEB419	6.	TMEB693
7.	I011368	8.	I980581
9.	I070593	10.	I920326

2.4 Experimental Design

The experiment was carried out in a factorial arrangement consisting of ten cassava genotypes, three treatments (and control) with six replications laid out in a randomized complete block design (RCBD); making a total of 240 experimental units.

The treatments were : Cassava + Water stress (T1), Cassava+ NaCl salinity (T2) and Cassava + Water stress + salt stress, D×S (T3) (Plate 3). Cassava + watering, control (T0).

2.5 Planting and Cultural Practices e.g. Weeding and Watering

Each bagged soil was watered to field capacity and the cassava stakes were planted in the soil in a slanting position with the buds facing upward. All plants were watered for 6 weeks before exposing them to the physiological stresses of drought, salinity and their interaction (D×S). During the first 6 weeks, all plants were watered with (1 l) of water every other day. Afterwards, plants for control and salinity were watered (1 l) once a week while those of drought and D×S were watered (1 l) once in two weeks. The bags with the plants for D and D×S were sealed from the mouth with pins and masking tape in order to control water entry. Subsequently, removal of weeds was done as and when due.

2.6 Salt Application

The designated plants were subjected to salt stress by applying 100mM of NaCl salt solution once a week for (S) and once in two weeks for (D×S). The 100mM was derived by dissolving 5.86g of NaCl per 1litre of water.

2.7 Harvesting

The plants were harvested at six months (24 weeks) after planting (January-July, 2019). The plants were divided into two; shoot and tuberous roots and their fresh and dry weights were taken to determine yield.

2.8 Data Collected

2.8.1 Growth attributes

Data on morphological growth attributes such as plant height, number of leaf produced and dropped were collected according to the method described by [31] (at a week interval) from the fourth week after planting to the nineteenth week. Leaf area by [32]. Stem diameter was measured using the digital Veneer caliper.

Plate 3. Picture showing a section (treatment) of the cassava farm for the combined stress

2.8.2 Relative Water Content (RWC)

This was analyzed twice at the 10th and 17th weeks after application of treatments. The method of Silveira et al. [33] was adopted using fresh medial leaf detached from each experimental unit.

$$RWC = \frac{FW - DW}{TW - DW} X100 \quad (1)$$

Where FW, DW and TW are fresh, dry and turgid weights respectively.

2.8.3 Yield determination

All plants were harvested at the 24th week when the fresh weights of shoot and tuberous roots were obtained by weighing on an electronic weighing balance. Then, they were oven-dried at 80^o C for 8 days until constant weights were obtained.

2.9 Statistical Analysis

Data obtained in this study were recorded as means of replicates and analysed using GLM Procedures based on statistical Analysis of Variance (ANOVA) by using Statistical Analysis Software (IBMSAS 9.1). Means of the treatments and controls were also compared and separated using Duncan Multiple Range Test (DMRT) at significance level set at α .05.

3. RESULTS

3.1 *Growth Attributes*

The growth responses of the selected cassava genotypes to drought and salinity varied as presented in Tables 2- 4. For each stress, the growth parameters studied were plant height, number of leaves, numbers of leaf dropped, leaf area and stem diameter.

Generally, the significant effects of drought were observed for all the agronomic growth parameters except in stem diameter which gave an F-value of 1.36 with a significant level of 0.14 (Table 2). The effect of drought was least and most significant on the heights of IBA120008 (61.94 cm) with control value of 70.95 cm and I098510 (32.77 cm) 40.85 cm as control respectively. The stem diameter of I010040 (2.72 cm) was the least significantly reduced.

It was generally observed that salinity significantly affected all the agronomic growth attributes of all the cassava genotypes studied (Table 3), comparing among/between the stressed genotypes and their corresponding controls. The heights of IBA120008 (57.09 cm) and I920326 (35.24 cm) were the most and least tolerant to salinity respectively. The mean number of leaf of IBA120008 (19.92) and TMEB419 (13.07) were the least and most significantly affected respectively.

Table 1. Physiochemical characteristics of the soil sample collected for the experiment

Physical properties	
Clay (%)	6.60
Silt (%)	12.4
Sand (%)	81.10
Texture class	sandy loam
Chemical properties	
pH	6.6
Total Oxygen Content (%)	2.664
Total Nitrogen Content (%)	0.237
Exchange Acidity	0.54
Average phosphorus	3.55 (mg/kg)
Calcium	14.12 (Cmol/kg)
Magnesium	1.54 (Cmol/kg)
Potassium	0.25 (Cmol/kg)
Sodium	0.83 (Cmol/kg)
Manganese	188.00 (Cmol/kg)
Iron	48.90 (mg/kg)
Copper	0.65 (mg/kg)
Zinc	42.60 (mg/kg)

Table 2. Growth parameters of the selected cassava genotypes under Drought stress

	Plant height (cm)		No of leaf		No of leaf dropped		Leaf area (cm^2)		Stem diameter(cm)	
Genotypes	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
IBA120008	40	61.94^{a}	40	16.23^{ab}	37	0.44^{b}	37	27.34^{cde}	40	2.38^{ab}
I098510	33	32.77^{e}	33	12.06^{de}	22	0.82^{b}	32	35.03^{abcd}	21	0.80^{b}
I010040	42	43.66^{cbde}	42	12.69^{cde}	7	1.43^{ab}	43	25.21^{e}	32	2.72^{a}
I070539	42	39.44^{ed}	42	12.90^{cde}	26	0.27^{b}	43	30.52^{bcde}	30	0.96^{b}
TMEB419	31	37.65^{ed}	31	13.19^{cde}	17	0.18^{b}	31	33.47^{abcde}	18	1.01^{b}
TMEB693	32	51.47^{bc}	32	12.03^{e}	18	0.28^{b}	32	30.57^{bcde}	18	1.03^{b}
I011368	48	44.20^{cbd}	48	14.08^{bcde}	24	0.17^{b}	48	25.13^{e}	34	0.97^{b}
I980581	43	41.60^{cde}	43	15.30^{abc}	29	0.59^{b}	43	38.13^{ab}	30	1.06^{b}
I070593	39	39.89^{ed}	39	13.69^{bcde}	24	0.17^{b}	39	37.19^{ab}	26	0.92^{b}
I920326	32	38.65^{ed}	55	14.25^{bcde}	37	0.65^{b}	55	33.57^{abcde}	40	0.94^{b}
Control IBA120008	34	70.95^{a}	34	17.24^{a}	20	1.05^{b}	26	26.16^{de}	20	1.16^{b}
Control I098510	32	40.85^{cde}	32	13.72^{bcde}	20	0.45^{b}	31	35.35^{abcd}	20	0.94^{b}
Control I010040	35	47.68^{cbd}	35	15.43^{abc}	21	2.52^{a}	32	27.68^{cde}	21	0.97^{b}
Control I070539	34	39.48^{ed}	34	13.24^{cde}	20	0.10^{b}	34	27.56^{cde}	20	0.88^{b}
Control TMEB419	31	42.18^{cbde}	31	14.35^{bcd}	17	0.47^{b}	31	36.35^{abc}	18	1.15^{b}
Control TMEB693	34	52.49^{b}	34	12.12^{de}	20	0.50^{b}	34	30.57^{bcde}	21	1.01^{b}
Control I011368	34	48.45^{bcd}	34	16.41^{ab}	20	0.45^{b}	31	26.67^{de}	19	1.12^{b}
Control I980581	50	45.29^{cbd}	50	17.62^{a}	34	0.29^{b}	50	41.96^{a}	34	1.07^{b}
Control I070593	38	41.10^{cde}	38	14.26^{bcde}	30	0.17^{b}	38	29.13^{bcde}	24	0.92^{b}
Control I920326	54	41.05^{cde}	54	15.07^{abcd}	37	0.86^{b}	54	30.79^{bcde}	38	0.96^{b}
Alpha		0.05		0.05		0.05		0.05		0.05
Error Degrees of Freedom		761		761		459		748		504
Error Mean Square		410.66		30.38		3.33		276.62		5.94
Harmonic Mean of Cell Sizes		37.81		37.81		20.81		36.84		24.23
F Value		6.82		3.54		1.96		3.37		1.36
Sig		<0.00011		<0.00011		0.00931		<0.0001		0.14261

Mean values across each column having the same superscript letters are not significant according to DMRT.

Table 3. Growth parameters of the selected cassava genotypes under Salinity

	Plant height (cm)		No of leaf		No leaf dropped		Leaf area (cm^2)		Stem diameter(cm)	
Genotypes	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
IBA120008	34	57.09^{b}	26	16.92^{abc}	25	0.24^{b}	28	27.30^{cd}	27	0.61^{c}
I098510	42	42.19^{cdef}	33	$15.21^{abcdefg}$	28	0.39^{b}	32	44.27^{ab}	30	0.03^{b}
I010040	38	37.15^{ef}	38	13.32^{defg}	23	0.17^{a}	38	45.49^{a}	32	1.08^{b}
I070539	42	42.10^{cdef}	40	15.83^{abcdef}	24	0.25^{b}	43	36.08^{abcd}	26	0.96^{b}
TMEB419	28	37.51^{ef}	28	13.07^{fg}	15	0.13^{b}	28	32.87^{abcd}	21	1.85^{a}
TMEB693	36	49.72^{bcd}	36	13.19^{efg}	22	0.68^{b}	36	38.90^{abcd}	21	1.03^{b}
I011368	48	46.50^{bcdef}	48	16.45^{abcd}	30	0.00^{b}	48	28.80^{dc}	30	0.99^{b}
I980581	43	38.93^{edf}	43	16.39^{abcde}	28	0.07^{b}	43	44.52^{ab}	30	1.04^{b}
I070593	42	46.89^{bcde}	42	16.91^{abc}	25	0.24^{b}	44	37.90^{abcd}	30	0.97^{b}
I920326	43	35.24^{f}	43	$14.49^{abcdefg}$	27	0.30^{b}	43	31.20^{abcd}	30	0.98^{b}
Control IBA120008	34	70.95^{a}	34	17.24^{ab}	20	1.05^{b}	26	26.16^{d}	20	1.16^{b}
Control I098510	32	40.85^{cde}	32	13.72^{cdefg}	20	0.45^{b}	31	35.35^{abcd}	20	0.94^{b}
Control I010040	35	47.68^{bcde}	35	15.43^{abcdef}	21	2.52^{a}	36	27.68^{cd}	21	0.98^{b}
Control I070539	34	39.48^{edf}	34	13.24^{defg}	20	0.10^{b}	34	27.56^{c}	20	0.88^{b}
Control TMEB419	31	42.18^{cdef}	31	14.36^{bcdefg}	17	0.47^{b}	31	36.35^{abcd}	18	1.16^{b}
Control TMEB693	34	52.49^{bc}	34	12.12^{g}	20	0.50^{b}	34	30.57^{bcde}	21	1.00^{b}
Control I011368	34	48.45^{bcde}	34	16.41^{abcde}	20	0.45^{b}	31	26.67^{d}	19	1.11^{b}
Control I980581	50	45.29^{cdef}	50	17.62^{a}	34	0.29^{b}	50	41.96^{abc}	34	1.07^{b}
Control I070593	38	41.10^{edf}	38	14.26^{bcdefg}	23	0.17^{b}	38	29.13^{cd}	24	0.92^{b}
Control I920326	54	41.05^{edf}	54	$15.07^{abcdefg}$	37	0.86^{b}	54	30.60^{bcd}	38	0.97^{b}
Alpha		0.05		0.05		0.05		0.05		0.05
Error Degrees of Freedom		742		742		459		735		488
Error Mean Square		413.08		33.86		3.01		637.76		0.16
Harmonic Mean of Cell Sizes		36.85		36.85		22.85		36.29		24.27
F Value		5.58		2.84		2.23		2.30		6.90
Sig		<0.00011		<0.00011		0.0023		0.0013		<0.00011

Mean values across each column having the same superscript letters are not significant according to DMRT

Table 4. Growth parameters of the selected cassava genotypes under the combined stress of Drought and Salinity

	Plant height (cm)		No of leaf		No leaf dropped		Leaf area (cm^2)		Stem diameter(cm)	
Genotypes	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
IBA120008	49	67.45^{a}	49	17.74^{a}	45	0.36^{b}	49	31.30^{bcdefg}	45	0.86^{g}
I098510	47	48.37^{bcd}	47	16.92^{ab}	32	0.78^{b}	48	39.12^{ab}	33	1.08^{abcde}
I010040	53	45.86^{cbd}	53	13.21^{edf}	36	0.36^{b}	38	23.86^{g}	38	0.91^{g}
I070539	60	45.07^{bcd}	60	15.82^{abcd}	42	0.14^{b}	60	33.93^{bcdef}	44	0.97^{defg}
TMEB419	41	45.75^{cbd}	28	14.54^{bcdef}	26	0.27^{b}	41	38.65^{abc}	27	1.08^{abcdef}
TMEB693	57	50.41^{bc}	57	12.17^{f}	39	0.36^{b}	57	28.90^{defg}	42	1.00^{bcdefg}
I011368	64	49.60^{bc}	64	16.27^{abc}	46	0.59^{b}	63	30.07^{defg}	46	1.12^{abc}
I980581	51	40.85^{cde}	51	16.35^{abc}	35	0.80^{b}	51	36.37^{abcd}	37	1.11^{abcd}
I070593	42	46.67^{bcd}	42	13.10^{ef}	27	0.15^{b}	42	30.21^{defg}	27	0.93^{fg}
I920326	43	34.57^{e}	57	12.39^{f}	39	0.64^{b}	57	28.64^{defg}	40	0.98^{cdefg}
Control IBA120008	34	70.95^{a}	34	17.24^{a}	21	1.05^{b}	26	26.16^{eg}	20	1.16^{a}
Control I098510	32	40.85^{cde}	32	13.72^{cdef}	20	0.45^{b}	31	35.35^{abcde}	20	0.94^{efg}
Control I010040	35	47.68^{bcd}	35	15.43^{abcde}	20	2.52^{a}	36	27.68^{efg}	21	0.99^{cdefg}
Control I070539	34	39.48^{ed}	34	13.24^{edf}	20	0.10^{b}	34	27.56^{efg}	20	0.88^{g}
Control TMEB419	30	41.17^{cde}	30	14.10^{cdef}	16	0.50^{b}	30	36.48^{abcd}	17	1.14^{ab}
Control TMEB693	34	52.49^{b}	34	12.12^{f}	20	0.50^{b}	34	30.57^{cdefg}	21	1.00^{bcdefg}
Control I011368	34	48.45^{bcd}	34	16.41^{abc}	20	0.45^{b}	31	26.67^{fg}	19	1.11^{abcd}
Control I980581	50	45.29^{bcd}	50	17.62^{a}	34	0.29^{b}	50	41.96^{a}	34	1.07^{abcdef}
Control I070593	38	41.10^{cde}	38	14.26^{bcdef}	23	0.17^{b}	38	29.13^{defg}	24	0.92^{g}
Control I920326	54	41.05^{cde}	54	15.07^{abcde}	37	0.87^{b}	54	30.80^{cdefg}	38	0.97^{efg}
Alpha		0.05		0.05		0.05		0.05		0.05
Error Degrees of Freedom		876		876		578		865		593
Error Mean Square		368.45		28.45		3.73		258.81		0.05
Harmonic Mean of Cell Sizes		42.43		42.43		26.95		41.38		27.50
F Value		8.70		5.59		1.73		4.06		4.60
Sig		<0.00011		<0.00011		0.0281		<0.00011		<0.00011

Means values across each column having the same superscript letters are not significant according to DMRT.

Table 5. Relative Water Contents of the selected cassava genotypes under Drought, Salinity and their combination

	Drought		Salinity		Drought and Salinity	
Genotypes	**Initial RWC %**	**Final RWC %**	**Initial RWC %**	**Final RWC %**	**Initial RWC %**	**Final RWC %**
IBA120008	90.15^{ab}	96.06^{ab}	90.00^{a}	63.64^{f}	93.98^{ab}	99.98^{b}
I098510	85.30^{c}	100.00^{ab}	89.90^{a}	91.74^{bcd}	95.83^{ab}	76.39^{ef}
I010040	92.71^{ab}	99.21^{ab}	98.45^{a}	99.45^{ab}	99.95^{a}	100.00^{a}
I070539	89.48^{ab}	98.04^{ab}	95.07^{a}	88.81^{bcd}	99.94^{a}	99.87^{bcde}
TMEB419	95.83^{ab}	100.00^{a}	97.73^{a}	99.50^{ab}	93.62^{ab}	99.94^{bc}
TMEB693	99.26^{a}	89.75^{b}	95.89^{a}	91.17^{bcd}	89.48^{abc}	99.91^{bcd}
I011368	89.68^{ab}	99.88^{ab}	95.70^{a}	96.43^{bcd}	92.09^{ab}	99.90^{bcd}
I980581	71.60^{d}	99.92^{a}	94.48^{a}	100.00^{a}	88.61^{abc}	98.61^{de}
I070593	100.00^{a}	90.39^{b}	94.61^{a}	99.15^{abc}	98.45^{ab}	55.56^{f}
I920326	88.98^{ab}	90.88^{b}	88.77^{a}	99.66^{ab}	91.20^{ab}	99.37^{de}
C IBA120008	80.03^{c}	94.01^{ab}	80.03^{a}	94.01^{bcd}	80.03^{c}	94.01^{de}
C I098510	88.46^{ab}	85.78^{c}	88.46^{a}	85.78^{bcd}	88.46^{abc}	85.78^{de}
C I010040	83.55^{c}	75.49^{d}	83.55^{a}	75.49^{e}	83.55^{c}	75.49^{ef}
C I070539	82.68^{c}	84.28^{c}	82.68^{a}	84.28^{d}	82.68^{c}	84.28^{de}
C TMEB419	88.89^{ab}	89.47^{b}	88.89^{a}	89.47^{bcd}	88.89^{abc}	89.47^{de}
C TMEB693	88.00^{ab}	78.57^{c}	88.00^{a}	78.57^{d}	88.00^{abc}	78.57^{ef}
C I011368	82.76^{c}	91.54^{b}	82.76^{a}	91.54^{bcd}	82.76^{c}	91.54^{de}
C I980581	88.55^{ab}	88.54^{b}	88.55^{a}	88.54^{bcd}	88.55^{abc}	88.54^{de}
C I070593	87.02^{abc}	82.41^{c}	87.02^{a}	82.41^{d}	87.02^{abc}	82.41^{de}
C I920326	81.25^{c}	77.68^{d}	81.25^{a}	77.68^{d}	81.25^{c}	77.68^{ef}
Df	41	42	43	43	54	54
Standard Error of the mean	3.32	3.38	12.84	10.03	11.74	13.82
Sum of Square	3223.68	5363.58	4412.24	5296.89	4413.23	8296.87
Harmonic Mean of Cell Sizes	87.71	91.28	89.59	92.93	89.85	109.01
F Value						
Sig	3.50	10.96	1.20	8.96	4.51	7.32
	0.001	<.0001	0.322	<0.0001	<.0001	<.0001

Values are means of three replicates, values across each column having the same superscript letters are not significant according to DMRT.

Generally, it was observed that the combined stress had significant effect on all the growth parameters of all the selected genotypes (Table 4).The heights of IBA120008 (67.45 cm) and I920326 (34.57 cm) were again the most and least tolerant respectively. With regards to the mean leaf area, I098510 (39.12cm^2) and I010040 (3.83cm^2) were the least and most significantly reduced respectively. For stem diameter, the least and most significantly reduced were I098510 (1.08 cm) and IBA120008(0.86 cm) respectively.

3.2 Relative Water Content (RWC)

All the screened genotypes showed considerable levels of tolerance to the stresses. Generally, drought and salinity with their combination had significant effects on the RWC of the selected cassava genotypes screened (Table 5).

At the initial stage of drought, I070593 (100.00) and I980581 (71.60) had the highest and lowest RWC (%) respectively. At the final stage, the highest and lowest RWC among the drought stressed genotypes were recorded for TMEB419 (100.00) and TMEB693 (89.75) respectively.

For the initial RWC (%), the most and least tolerant to salinity were I010040 (98.45) and I920326 (88.77) respectively while they were I980581 (100.00) and IBA120008 (63.64) respectively; for the final RWC (%).

For the combined stress, the highest and lowest initial RWC (%) were recorded in I010040 (99.95) and I980581 (88.61) respectively but were I010040 (100.00) and I070593 (55.56) for the final RWC respectively.

Table 6. The yield parameters of selected cassava genotypes under drought stress

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	185.57^{ab}	78.42^{b}	4.33^{bc}	74.53^{c}	15.81^{bc}
I098510	98.94^{c}	35.50^{c}	4.33^{bc}	76.07^{c}	18.30^{bc}
I010040	59.14^{c}	25.18^{c}	2.00^{e}	42.12^{d}	10.43^{e}
I070539	221.95^{abc}	86.95^{a}	3.33^{d}	65.98^{cd}	16.62^{c}
TMEB419	158.83^{ab}	67.02^{bc}	6.00^{b}	125.88^{b}	27.87^{b}
TMEB693	66.39^{c}	29.64^{d}	3.33^{d}	23.97^{e}	4.35^{f}
I011368	105.40^{ab}	51.31^{bc}	7.33^{c}	143.37^{ab}	34.62^{b}
I980581	97.96^{c}	42.23^{c}	6.67^{c}	174.54^{a}	29.48^{b}
I070593	138.62^{ab}	65.96^{bc}	3.67^{d}	80.56^{c}	17.42^{c}
I920326	97.24^{c}	37.03^{c}	3.33^{d}	82.98^{bc}	15.15^{bc}
Control IBA120008	166.73^{ab}	69.43^{bc}	5.33^{b}	56.17^{d}	13.02^{d}
Control I098510	172.82^{ab}	73.23^{b}	2.50^{e}	147.09^{ab}	26.39^{b}
Control I010040	256.49^{abc}	89.18^{a}	3.67^{d}	75.43^{c}	9.97^{d}
Control I070539	140.67^{ab}	58.55^{bc}	4.33^{bc}	109.18^{b}	23.48^{b}
Control TMEB419	125.17^{ab}	49.30^{c}	8.00^{a}	178.94^{a}	42.51^{ab}
Control TMEB693	233.49^{abc}	96.04^{a}	2.00^{e}	95.58^{b}	23.82^{b}
Control I011368	268.57^{abc}	86.77^{a}	4.67^{bc}	99.99^{b}	20.76^{b}
Control I980581	158.45^{ab}	50.52^{bc}	5.33^{b}	253.61^{a}	68.75^{a}
Control I070593	76.59^{c}	33.05^{c}	2.00^{e}	49.36^{d}	11.12^{d}
Control I920326	132.20^{ab}	39.84^{c}	5.33^{b}	185.62^{a}	32.22^{b}
N	54.00	54.00	56.00	56.00	56.00
Alpha	0.05	0.05	0.05	0.05	0.05
Df	53	53	55	55	55
Standard Error of the mean	12.48	4.79	0.28	9.49	2.34
Sum of Square	445746.30	65516.89	248.21	277110.30	16819.86
Harmonic Mean of Cell Sizes	148.04	57.94	4.32	103.97	22.34
F Value	1.44	1.10	2.31	3.46	3.46
Sig	0.173	0.397	0.015	0.001	0.001

Mean values across each column having the same superscript letters are not significant according to DMRT.

3.3 Yield Parameters

Here, the yield attributes of the screened genotypes also responded variably to the stresses (Tables 6-8).The yield attributes studied were shoot fresh weights (SFW), shoot dry weights (SDW), Number of tuber (NOT), tuber fresh weights (TFW) and tuber dry weights (TDW). Generally, all the parameters were significantly affected by drought except the SFW and SDW. The SDW of I070539 (86.95g) and TMEB693 (29.64g) were the least and most significantly reduced by drought respectively. Comparing the stressed genotypes with their corresponding controls (C), I920326 (82.98g) with C as 185.62g for instance was significantly reduced.

Generally salinity significantly affected all the yield parameters except SDW. Genotype I980581 was the most tolerant as it produced the highest number of tubers (8.00) here. For tuber FW, I980581 (350.78g) and IBA120008 (39.53g) were the most and least tolerant respectively.

Generally, the combined stress had similar effect as salinity. Comparing the stressed genotypes with their C, the SFW of I010040 (79.77g) with C as 256.49g was greatly reduced by the combined stress of drought and salinity. Again, the TFW of I980581(224.17g) was the most tolerant while I010040 (16.80g) was the least.

4. DISCUSSION

Cassava has been severally ascertained to tolerate unfavourable environmental and soil conditions to appreciable extent. The selected cassava genotypes screened in this study showed varying levels of tolerance with respect to the parameters studied.

Table 7. The yield parameters of selected cassava genotypes under salinity stress

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	109.43^{cd}	43.92^{cd}	1.00^{e}	39.53^{e}	08.76^{d}
I098510	253.14^{a}	69.92^{ab}	4.33^{ab}	163.49^{ab}	36.97^{bc}
I010040	161.34^{c}	84.38^{a}	2.67^{cd}	106.09^{c}	20.11^{c}
I070539	173.91^{c}	67.80^{ab}	4.33^{ab}	103.93^{c}	23.72^{c}
TMEB419	72.10^{de}	29.81^{d}	7.00^{a}	110.81^{c}	29.01^{c}
TMEB693	92.02^{de}	41.87^{c}	3.00^{c}	109.14^{c}	31.70^{bc}
I011368	88.88^{de}	41.45^{c}	5.33^{b}	109.29^{c}	26.17^{c}
I980581	192.59^{bc}	79.04^{a}	8.00^{a}	350.78^{a}	77.18^{a}
I070593	84.58^{de}	38.68^{d}	4.00^{ab}	70.67^{d}	13.40^{d}
I920326	227.01^{b}	67.62^{ab}	5.33^{b}	197.72^{b}	37.14^{bc}
Control IBA120008	111.15^{d}	69.43^{ab}	5.33^{b}	56.17^{cd}	13.02^{d}
Control I098510	115.21^{d}	73.23^{ab}	2.50^{cd}	147.09^{b}	26.39^{c}
Control I010040	256.49^{a}	89.18^{a}	3.67^{c}	75.43^{d}	09.97^{d}
Control I070539	140.67^{c}	58.55^{c}	4.33^{ab}	109.18^{c}	23.48^{c}
Control TMEB419	41.72^{e}	30.31^{d}	8.00^{a}	178.94^{b}	42.51^{b}
Control TMEB693	155.66^{c}	96.04^{a}	2.00^{d}	95.58^{c}	23.82^{c}
Control I011368	268.57^{a}	86.77^{a}	4.67^{ab}	99.99^{c}	20.76^{c}
Control I980581	158.45^{c}	50.52^{c}	5.33^{b}	253.61^{a}	68.75^{a}
Control I070593	76.59^{de}	33.05^{d}	2.00^{c}	49.36^{e}	11.12^{d}
Control I920326	132.20^{c}	39.84^{d}	5.33^{b}	185.62^{b}	32.22^{bc}
N	60.00	50.00	51.00	51.00	51.00
Alpha	0.05	0.05	0.05	0.05	0.05
Df	59.00	49.00	50.00	50.00	50.00
Standard Error of the mean	14.82	4.74	0.32	15.58	3.74
Sum of Square	777423.00	54923.60	264.71	619212.60	35633.40
Harmonic Mean of Cell Sizes	142.44	61.66	4.53	135.43	29.75
F Value	22.41	0.77	2.03	12.007	81.24
Sig	<0.00011	0.717	0.038	<0.00011	<0.00011

Mean values across each column having the same superscript letters are not significant according to DMRT.

Generally, drought had significant effects on all the growth parameters of genotypes studied except the stem diameter (but was on each genotypes at differed rates). Water deficit lowers turgor pressure which in turn greatly reduces cell expansion and cell growth [34]. Oyetunji et al. [35], reported a reduction in the growth of cassava by drought. Leaf area is greatly related to photosynthesis and yield. Reduction in leaf area is a measure to reduce water loss through transpiration but this in turn reduces photosynthesis and hence, yield. Reduction in leaf area was also reported in soybean [36]. Decreased irrigation dose caused reduction in the plant height and leaf area of cassava [37].

Salinity had significant effects on the growth parameters of all the genotypes studied as the control values were in most cases significantly different from the treatment values. Salinity reduced growth in barley [38], cassava [7] and cowpea [2]. Salinity significantly reduced seedling height, leaf number and area in cotton [32]. Contrary to the present study, drought or salinity had insignificant effect on growth of quinoa [39].

Salinity increased growth in wheat [40].Increased NaCl concentration inhibited cassava growth [17,41].

The combination of drought and salinity had similar effect as salinity. Both drought and salinity impose osmotic effects on plants but the latter can also cause ion toxicity. Drought and salinity reduced shoot length in grapevines [42]. Interactive effects of these stresses reduced growth in amaranth [43].

Table 8. The yield parameters of selected cassava genotypes under the combined stresses of drought and salinity

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	160.87^{ab}	52.46^{c}	4.00^{b}	84.30^{b}	17.26bc
I098510	124.93^{ab}	51.93^{c}	5.00^{a}	180.84^{a}	44.47^{b}
I010040	79.77^{c}	34.58^{d}	2.00^{c}	16.80^{e}	3.45^{d}
I070539	103.09^{b}	43.23^{c}	4.67^{b}	154.69^{ab}	37.79^{b}
TMEB419	28.44^{d}	20.62^{d}	6.00^{a}	161.71^{ab}	44.10^{b}
TMEB693	162.73^{ab}	81.13^{a}	2.33^{c}	48.64^{c}	13.06^{c}
I011368	96.80^{ab}	45.57^{c}	8.67^{a}	142.28^{ab}	26.88^{bc}
I980581	73.98^{c}	37.54^{cd}	5.00^{b}	224.17^{a}	56.97^{a}
I070593	109.83^{ab}	59.45^{c}	3.67^{b}	28.64^{d}	5.45^{d}
I920326	86.07^{c}	42.84^{c}	4.33^{b}	134.44^{ab}	18.01b^{c}
Control IBA120008	111.15^{b}	69.43^{b}	5.33^{a}	56.17^{c}	13.02^{c}
Control I098510	115.21^{b}	73.23^{b}	2.50^{c}	147.09^{a}	26.39^{bc}
Control I010040	256.49^{a}	89.18^{a}	3.67^{b}	75.43^{bc}	9.97^{d}
Control I070539	140.67^{ab}	58.55^{c}	4.33^{b}	109.18^{ab}	23.48^{bc}
Control TMEB419	41.72^{d}	49.30^{c}	8.00^{a}	178.94^{a}	42.51^{b}
Control TMEB693	155.66^{ab}	96.04^{a}	2.00^{c}	95.58^{ab}	23.82^{bc}
Control I011368	268.57^{a}	86.77^{a}	4.67^{b}	99.99^{ab}	20.76^{bc}
Control I980581	158.45^{ab}	50.52^{c}	5.33^{a}	253.61^{a}	68.75^{a}
Control I070593	76.59^{c}	33.05^{d}	2.00^{c}	49.36^{c}	11.12^{d}
Control I920326	132.20^{ab}	39.84^{c}	5.33^{a}	185.62^{a}	32.22^{b}
N	60	54	55	55	55
Alpha	0.05	0.05	0.05	0.05	0.05
Df	59	53	54	54	54
Standard Error of the mean	11.42	4.32	0.33	10.80	3.003
Sum of Square	6323.62	953.51	4.97	3412.25	296.89
Harmonic Mean of Cell Sizes	124.16	55.33	4.44	121.18	26.90
F Value	3.39	1.16	8.99	3.51	2.91
Sig	<.0001	0.342	<.0001	0.001	0.003

Mean values across each column having the same superscript letters are not significant according to DMRT.

Although in this study; drought, salinity and their combination did not have significant effects on RWC both at the initial and final stages on a general note, they did among the studied genotypes which showed varying degrees of tolerance among them to these treatments.

Genotypes with higher RWC may be due to their ability to exhibit high water use efficiency (WUE) under drought [39]. Drought greatly reduced RWC in maize [24], cassava [44] and potato [45].

Salinity reduced RWC in maize [46] and rice [47]. Reduction in RWC by drought, salinity and their combination was observed in amaranth [43].

Generally, all the yield parameters were significantly affected by drought except the SFW and SDW but each genotype responded differently. Drought reduced yield in common bean and green gram [48], maize [49] and cassava [44]. The reports of the present study was in line with earlier studies on cassava [50,51].

Generally, it was observed that salinity; and the combined stress significantly affected all the yield parameters of the genotypes except their SDWs. This was in line with the reports of Saleh [32], in cotton where salinity significantly affected root and shoot weight ratio, and [38,52], where salinity reduced shoot dry, and fresh mass in barley. Salinity [46] and drought reduced shoot fresh and dry weights in maize [53]. A contrasting report was given on wheat regarding salinity [40].[17] reported a reduction in cassava biomass by salinity.

5. CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that while some genotypes like IBA120008 channeled majority of their resources to shoot growth than tuber formation (yield), it is the other way round in genotypes like I980581 which had the highest tuber yield under the three treatments they were screened for.

It can also be concluded that the above stresses reduced yield of the selected cassava genotypes although, drought affected yield than salinity and their combination.

Hence, I recommend that growth parameters like height should not be used alone for screening cassava but in conjunction with other parameters as it was ascertained in IBA120008 and I980581 that high shoot growth does not guarantee high yield.

SUPPLEMENTARY MATERIALS

The material in (Supplementary table 9 in available in this following link:
https://www.journalajrib.com/index.php/AJRIB/libraryFiles/downloadPublic/2

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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